CLAIMS:

1. A position determining system comprising:

a first member and a plurality of second members, the first and second members being movable relative to each other and the position of each of the second members relative to the other second members being known;

wherein the first and second members are arranged so that upon the transmission of a signal comprising first and second different frequency components between the first member and the plurality of second members, there is generated a plurality of received signals each associated with a respective transmission path between a respective second member and the first member;

means for processing each received signal to determine a corresponding phase measurement for the first frequency component thereof and a corresponding phase measurement for the second frequency component thereof;

a first phase differencing means for calculating, for each received signal, a phase difference between the phase measurements of the first and second frequency components of the received signal, to generate a first set of phase difference measurements;

a first position determining means for determining a first position measurement of the relative position of the first member and the plurality of second members from the first set of phase difference measurements and the known relative positions of the second members;

a second phase differencing means for calculating phase difference measurements between phase measurements of frequency components of different received signals, to generate a second set of phase difference measurements;

a second position determining means for determining a second position measurement of the relative position between the first member and the plurality of second members from the second set of phase difference measurements and the known relative positions of the second members; and

means for determining the relative position between the first member and the plurality of second members using the first and second position measurements.

2. A system according to claim 1, wherein said relative position determining means forms part of said second position determining means, wherein said second position measurement includes a phase ambiguity and wherein said relative position determining means is operable to use the first position measurement to resolve the phase ambiguity associated with the second position measurement to determine the relative position between the first member and the plurality of second members.

3. A position determining system according to claim 1, wherein said relative position determining means is operable to determine the relative position between the first member and the plurality of second members by performing a weighted combination of the first and second position measurements.

4. A system according to claim 1, wherein said relative position determining means is operable to determine the relative position between the first member and the plurality of second members by averaging the first and second position measurements.

5. A system according to claim 1, wherein said relative position determining means forms part of said first position determining means, wherein said first position measurement includes a phase ambiguity and wherein said relative position determining means is operable to use the second position measurement to resolve the phase ambiguity associated with the first position measurement to determine the relative position between the first member and the plurality of second members.

6. A system according to any preceding claim, wherein said first position determining means is operable to perform an iterative processing routine to determine said first position measurement using said first set of phase difference measurements.

7. A system according to any preceding claim, wherein said second position determining means is operable to perform an iterative processing routine to determine said second position measurement using said second set of phase difference measurements.

8. A system according to any preceding claim, wherein said first member comprises a transmitter for transmitting said signal and wherein said plurality of second members each comprise a receiver for receiving the transmitted signal and for generating a respective one of said received signals.

9. A system according to any of claims 1 to 7, wherein each of said plurality of second members comprises a transmitter for transmitting said signal and wherein said

first member comprises a receiver for receiving the signal transmitted by each of the second members to generate said received signals.

10. A system according to any preceding claim, comprising a plurality of first members,

wherein the plurality of first and second members are arranged so that upon the transmission of a signal comprising first and second different frequency components between each first member and the plurality of second members, there is generated a plurality of sets of received signals, each set being associated with a respective one of the first members and the received signals in each set being associated with the respective transmission path between a respective second member and the associated first member;

wherein said first phase differencing means is operable to calculate a first set of phase difference measurements associated with each first member;

wherein said first position determining means is operable to determine a first position measurement of the relative position of each first member and the plurality of second members from the first set of phase difference measurements associated with the first member and the known relative positions of the second member;

wherein said second phase differencing means is operable to calculate a second set of phase difference measurements for each first member;

wherein said second position determining means is operable to determine a second position measurement of the relative position between each first member and the plurality of second members from the second set of phase

difference measurements for the first member and the known relative positions of the second members; and

wherein said relative position determining means is operable to determine the relative position between each first member and the plurality of second members using the corresponding first and second position measurements.

11. A position determining system comprising:

a transmitter being operable to transmit a signal comprising first and second frequency components having a frequency spacing therebetween;

a plurality of receivers having known relative positions, each being operable to receive the signal transmitted from the transmitter;

means for processing the signal received at each receiver to determine, for each received signal, a phase measurement for the first frequency component and a phase measurement for the second frequency component;

means for calculating a phase difference measurement for each received signal from the determined phase measurements for the corresponding received signal; and

means for determining the relative position between the transmitter and the receivers on the basis of the calculated phase difference measurements for the received signals and the known relative positions of the receivers.

12. The system of claim 11, wherein a separate processing means is provided for each receiver which is located at the corresponding receiver and which is operable to determine the phase measurements for the signal received at the corresponding receiver.

13. The system of claim 11 or 12, wherein said calculating means and said determining means are located within a central processing station, and wherein said processing means is operable to transmit said phase measurements to said central processing station.

14. The system of any of claims 11 to 13, wherein the transmitter is operable to transmit the first frequency component and the second frequency component alternately.

15. The system of any of claims 11 to 14, wherein the transmitter is operable to transmit pulses of said signal, wherein said processing means is operable to determine a phase measurement for the first and second frequency components during each pulse of said transmitted signal, wherein said calculating means is operable to calculate a phase difference measurement for each received signal during each pulse and wherein said determining means is operable to determine a position of the transmitter at the time of each pulse on the basis of the calculated phase difference measurements for the received signals for the corresponding pulse and the known relative positions of the receivers.

16. The system of claim 15, wherein the transmitter is operable to maintain phase continuity between transmitted pulses of said signal.

17. The system of claim 15 or 16, wherein the transmitter comprises a single clock from which said first and second frequency components are derived.

18. The system of claim 15, 16 or 17, wherein said processing means is operable to determine the phase of each frequency component at each of a plurality of different times during each pulse and wherein said determined phase measurement for each frequency component comprises a phase offset value corresponding to the phase of the respective component at one of said times and a phase slope measurement indicative of the rate at which the determined phase of said frequency component changes during each pulse.

19. The system of claim 18, wherein said processing means is operable to perform repeated frequency analysis of said received signals to determine said phase measurements.

20. The system of claim 19, wherein said processing means is operable to perform repeated frequency transforms of the received signals to determine said phase offset measurement and said phase slope measurement.

21. The system of claim 19 or 20, wherein said processing means repeatedly performs said frequency analysis on each received signal and further comprises means for storing a reference pattern representative of an expected result of the frequency analysis of the signal transmitted by the transmitter; and means for comparing the results of said repeated frequency analysis with said reference pattern to identify a received pulse of the transmitted signal.

22. The system of any of claims 18 to 21, wherein said calculating means is operable to calculate a phase difference measurement for both said phase offset measurement and said phase slope measurement.

23. The system of any of claims 18 to 22, further comprising means for determining the position of said transmitter between or after transmitted pulses by interpolating or extrapolating from determined positions at the pulses.

24. The system of any of claims 11 to 23, comprising a plurality of transmitters, each operable to transmit a respective signal comprising first and second frequency components, wherein said plurality of receivers are operable to receive the signal transmitted from each transmitter, wherein said processing means is operable to process the signal received at each receiver from each transmitter to determine, for each received signal, said phase measurement for the first frequency component and said phase measurement for the second frequency component, wherein said calculating means is operable to calculate a phase difference measurement for each received signal and wherein said determining means is operable to determine the position of each transmitter on the basis of the calculated phase difference measurements for the received signals from the corresponding receiver and the known relative positions of said receivers.

25. The system of claim 24, wherein each transmitter is operable to transmit on different frequencies.

26. The system of claim 24 or claim 25, wherein each transmitter is operable to transmit pulses of said signal at a different repeat interval.

27. The system of any of claims 11 to 26, wherein the or each transmitter is operable to transmit said signal comprising said first and second frequency components having a predetermined frequency spacing therebetween.

28. The system of any of claims 11 to 27, wherein the or each transmitter comprises means for changing the transmission frequency of said first and second frequency components.

29. The system of claim 28, wherein said changing means is operable to maintain the same frequency spacing between said first and second frequency components.

30. The system of claim 28 or 29, wherein the changing means is operable to change the transmit frequencies according to a predetermined schedule.

31. The system of any of claims 11 to 30, wherein the transmitter is operable to transmit said signal as a spread spectrum signal.

32. The system of claim 31, wherein the transmitter is operable to generate said spread spectrum signal by combining said signal with a pseudo-noise code and wherein said processing means comprises a correlator for correlating the received signal with a copy of the pseudo-noise code to determine said phase measurement for

each of said first and second frequency components.

33. The system of claim 31 or 32 when dependent on claim 24, wherein each transmitter uses a pseudo-noise code unique to that transmitter.

34. The system of any of claims 11 to 33, wherein the transmitter is operable to transmit a signal comprising first, second and third frequency components, each having a frequency spacing from the other frequency components, wherein said processing means is operable to determine a phase measurement for each frequency component, wherein said calculating means is operable to determine a plurality of phase difference measurements for each received signal from the determined phase measurements for the first, second and third frequency components of the received signal, and wherein said determining means is operable to determine the relative position of the transmitter on the basis of the calculated phase difference measurements for the received signals and the known relative positions of the receivers.

35. The system according to claim 34, wherein the frequency spacing between the first and second frequency components is greater than the frequency spacing between the second and third frequency components and wherein the phase difference measurements obtained from the phase difference measurements of the first and second frequency components are operable to provide a coarse position measurement and wherein the phase difference measurements obtained from the phase measurements of the second and third frequency components are used to determine a fine

position measurement.

36. The system of claim 35, which is operable to determine the relative position of said transmitter over a predetermined range and wherein said frequency spacing between said first and second frequency components is chosen so that said coarse position measurement provides an absolute position measurement within said range.

37. The system of claim 36, wherein the frequency spacing between said second and third frequency components is determined so that said fine position measurement includes a cyclic ambiguity within said range and wherein said coarse position measurement is used to resolve said cyclic ambiguity.

38. The system of claim 35, 36 or 37, wherein said determining means is operable to determine the position of the transmitter using an iterative numerical technique, with the coarse position measurement being used to initialise the iterative processing to determine said fine position measurement.

39. The system of any of claims 11 to 38, wherein said receivers are unsynchronised and further comprising a reference transmitter whose position relative to said receivers is known and operable to transmit a reference signal having first and second frequency components with a frequency spacing therebetween, wherein said plurality of receivers are operable to receive the reference signal transmitted from the reference transmitter, wherein said processing means is operable to process the reference

signal received at each receiver to determine for each received reference signal, a phase measurement for the first frequency component and a phase measurement for the second frequency component, wherein said calculating means is operable to calculate a phase difference measurement for each received reference signal from the determined phase measurements for the corresponding received reference signal and further comprising:

means for determining a respective calibration value for each receiver from the calculated phase difference measurements for the received reference signals, the known relative positions of the receivers and the known relative position of the reference transmitter; and

means for adjusting said phase measurements using said calibration values to account for the lack of synchronisation of said receivers.

40. The system of claim 39, wherein said adjusting means is operable to adjust said phase difference measurements using said calibration values.

41. The system of claim 39 or 40, comprising a plurality of said reference transmitters.

42. The system of claim 41, wherein each reference transmitter is located at a corresponding receiver.

43. The system of any of claims 11 to 42, wherein said transmitter is a transmit-only transmitter and operates asynchronously with respect to said receivers.

44. The system of any of claims 11 to 43, further

comprising a plurality of tracking loops for tracking and smoothing each of the calculated phase difference measurements.

45. The system of claim 44, wherein each tracking loop comprises a phase locked loop.

46. The system of any of claims 11 to 45, wherein said determining means is operable to determine a two-dimensional position of said transmitter.

47. The system of claim 46, wherein three receivers are provided and wherein said determining means is operable to determine the absolute position of said transmitter in two dimensions.

48. The system of any of claims 11 to 46, wherein said determining means is operable to determine the position of said transmitter in three dimensions.

49. The system of any of claims 11 to 48, wherein said determining means is operable to determine the relative position between the transmitter and the receivers on the basis of the distance between the transmitter and each receiver from said phase difference measurements.

50. The system of any of claims 11 to 49, comprising a reference transmitter whose position is known relative to said receivers and operable to transmit a signal comprising first and second frequency components having a frequency spacing therebetween; and wherein said receivers, said processing means and said calculating

means are operable to process a signal from said reference transmitter to generate calibration values for use in calibrating the phase measurements from said transmitter.

51. The system of claim 50, wherein said calibration values are repeatedly updated and used to dynamically alter the phase measurements from the transmitter in order to reference the measurements from the transmitter to a clock within said reference transmitter.

52. A transmitter for use in the system according to any of claims 11 to 51, comprising:

a clock for generating a clock signal;

means for receiving the clock signal and for generating therefrom a plurality of frequency components having a frequency spacing therebetween; and

means for transmitting a signal comprising said plurality of frequency components.

53. The transmitter of claim 52, wherein said generating means is operable to generate pulses of said plurality of frequency components whilst maintaining phase continuity between the pulses.

54. The transmitter of claim 52 or 53, wherein said generating means is operable to generate said plurality of frequency components in sequence.

55. The transmitter of any of claims 52 to 54, wherein said generating means comprises a frequency synthesiser which is operable to generate frequencies within a

predetermined frequency band and a programmable memory device which stores data defining the frequencies to be synthesised by said synthesiser.

56. The transmitter of claim 55, wherein said programmable memory device comprises data defining the start time and stop time of each frequency component synthesised by said synthesiser.

57. The transmitter of claim 55 or 56, wherein said programmable memory device comprises a field programmable gate array.

58. The transmitter of any of claims 55 to 57, wherein said synthesiser is a digital synthesiser and further comprising a digital to analogue converter for converting digital samples output from said digital synthesiser to generate a corresponding analogue frequency component.

59. A position processor for determining the position of a transmitter relative to a plurality of receivers, the receivers having known relative positions and being operable to receive a signal comprising first and second frequency components having a frequency spacing therebetween transmitted from the transmitter, the apparatus comprising:

means for receiving a plurality of sets of phase measurements, each set associated with a respective one of the receivers and each set comprising a phase measurement for the first frequency component and a phase measurement for the second frequency component of the signal received at the corresponding receiver;

means for calculating a phase difference measurement for each set of phase measurements; and

means for determining the relative position of the transmitter on the basis of the calculated phase difference measurements and the known relative positions of the receivers.

60. A position processor for determining the relative position between a first member and a plurality of second members, the first and second members being movable relative to each other and the position of each of the second members relative to the other second members being known and the first and second members being arranged so that upon the transmission of a signal comprising first and second different frequency components between the first member and the plurality of second members, there is generated a plurality of received signals each associated with a respective transmission path between a respective second member and the first member, the position processor comprising:

means for calculating, for each received signal, a phase difference between phase measurements of the first and second frequency components of the received signal; and

means for determining a position measurement of the relative position of the first member and the plurality of second members from the calculated phase differences and the known relative positions of the second members.

61. A position processor for determining the relative position between a first member and a plurality of second members, the first and second members being movable

relative to each other and the position of each of the second members relative to the other second members being known and the first and second members being arranged so that upon the transmission of a signal comprising first and second different frequency components between the first member and the plurality of second members, there is generated a plurality of received signals each associated with a respective transmission path between a respective second member and the first member, the position processor comprising:

a first phase differencing means for calculating, for each received signal, a phase difference between a phase measurement of the first and second frequency components of the received signal, to generate a first set of phase difference measurements;

a first position determining means for determining a first position measurement of the relative position of the first member and the plurality of second members from the first set of phase difference measurements and the known relative positions of the second members;

a second phase differencing means for calculating phase difference measurements between phase measurements of frequency components of different received signals, to generate a second set of phase difference measurements;

a second position determining means for determining a second position measurement of the relative position between the first member and the plurality of second members from the second set of phase difference measurements and the known relative positions of the second members; and

means for determining the relative position between

the first member and the plurality of second members using the first and second position measurements.

62. A position determining system according to claims 60 or 61, further comprising means for processing each received signal to determine a corresponding phase measurement for the first frequency component thereof and a corresponding phase measurement for the second frequency component thereof.

63. A position determining method for determining the relative position between a transmitter and a plurality of receivers, with the relative position of the receivers being known, the method comprising the steps of:

transmitting from the transmitter a signal comprising first and second frequency components having a frequency spacing therebetween;

receiving at each receiver the signal transmitted by the transmitter;

processing the signal received at each receiver to determine, for each received signal, a phase measurement for the first frequency component and a phase measurement for the second frequency component;

calculating a phase difference measurement for each received signal from the determined phase measurements for the corresponding received signal; and

determining the relative position between the transmitter and the receivers on the basis of the calculated phase difference measurements for the received signals and the known relative positions of the receivers.

64. A position determining system comprising:

a tag and a plurality of base stations, the tag being movable relative to the base stations and the position of each base station relative to the other base stations is known;

wherein the tag and the plurality of base stations are arranged so that upon the transmission of a signal comprising first and second frequency components having a frequency spacing therebetween from the tag to the base stations or from the base stations to the tag, there is generated a plurality of received signals each associated with a respective transmission path between a respective base station and the tag;

means for processing each received signal to determine a corresponding phase measurement for the first frequency component and a corresponding phase measurement for the second frequency component;

means for calculating a phase difference measurement for each received signal from the corresponding determined phase measurements; and

means for determining the relative position of the tag and the base stations on the basis of the calculated phase difference measurements for the received signals and the known relative positions of the base stations.

65. The system of claim 64, wherein said tag transmits said signal and wherein each of said base stations receives said signal.

66. The system of claim 64, wherein each of said base stations transmits said signal and wherein said tag receives each signal.

67. The system according to claim 66, wherein said processing means, calculating means and determining means are provided in the tag.

68. The system of claim 66, wherein said determining means is provided in a central processing system and wherein said tag is operable to transmit signals to said central processing system, which signals depend upon the signals received from said base stations.

69. The system of claim 68, wherein said processing means and said calculating means are provided within said central processing system.

70. Processor-implementable instructions for programming a programmable computer device to become configured as the position processor of any of claims 59 to 62.

71. Processor-implementable instructions for causing a programmable computer device to become configured as a transmitter according to any of claims 52 to 58.

72. A receiver for receiving a signal comprising first and second frequency components transmitted by a tag, the receiver comprising:

means for receiving the signal transmitted by the tag;

means for performing a repeated frequency analysis of the received signal to obtain a plurality of phase measurements for each frequency component in the received signal; and

means for processing the plurality of phase

measurements for each received frequency component to determine a phase measurement for each tone; and

means for outputting said phase measurements for transmission to a central position processor.

73. The receiver of claim 72, wherein said processing means is operable to determine a phase offset measurement and a phase slope measurement for each frequency component.

74. A receiver for receiving a plurality of signals transmitted from a plurality of transmitters each located at a different location and each transmitter being operable to transmit a signal comprising first and second different frequency components, the receiver comprising:

means for receiving the signals transmitted by said transmitters;

means for processing each received signal to determine a corresponding phase measurement for the first frequency component thereof and a corresponding phase measurement for the second frequency component thereof;

means for calculating, for each received signal, a phase difference between the phase measurements of the first and second frequency components; and

means for outputting said phase measurements for transmission to a central position processor.

75. A receiver for receiving a plurality of signals transmitted from a plurality of transmitters located at different locations, each transmitter being operable to transmit a signal having first and second different frequency components, the receiver comprising:

means for receiving the signal transmitted by each transmitter;

means for processing each received signal to determine a corresponding phase measurement for the first frequency component thereof and a corresponding phase measurement for the second frequency component thereof;

a first phase differencing means for calculating, for each received signal, a phase difference between the phase measurements of the first and second frequency components of the received signal, to generate a first set of phase difference measurements;

a second phase differencing means for calculating phase difference measurements between phase measurements of frequency components of different received signals, to generate a second set of phase difference measurements; and

means for outputting said first and second set of phase difference measurements for transmission to a central position processor.

76. Processor implementable instructions for causing a programmable processor device to become configured as the receiver of any of claims 72 to 75.